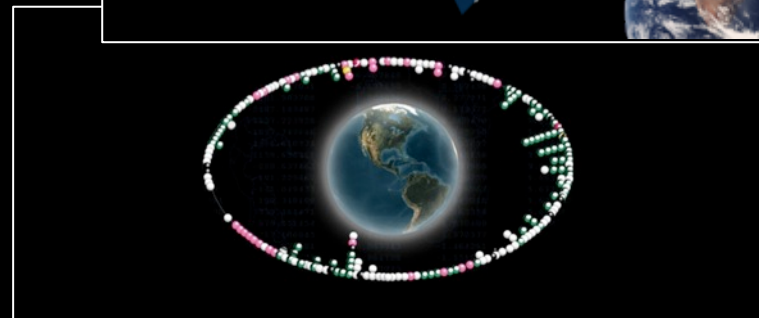
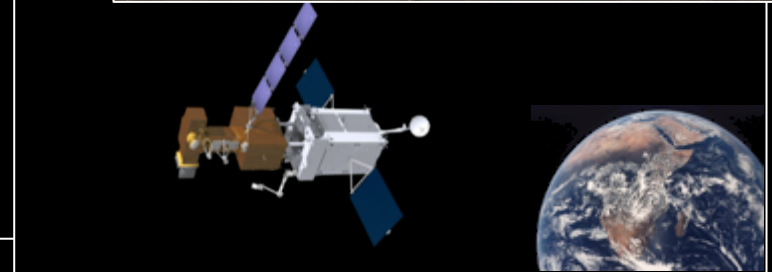
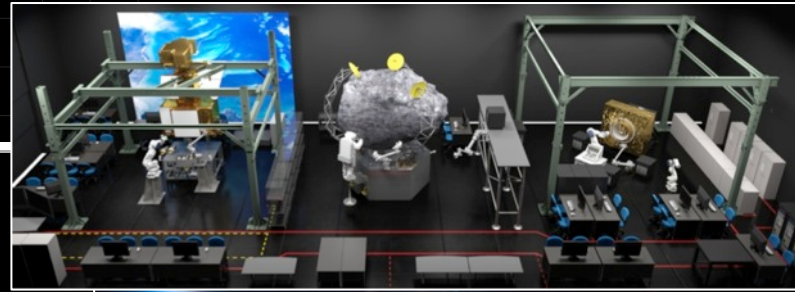


# In Orbit Servicing: The Master Enabler

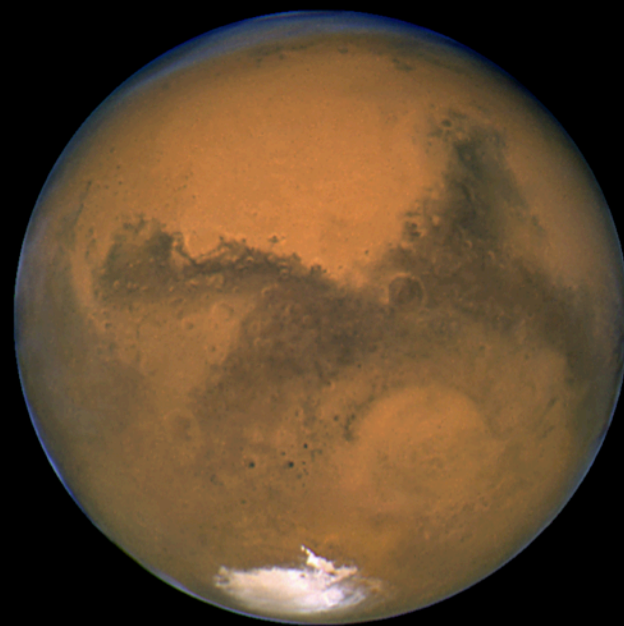
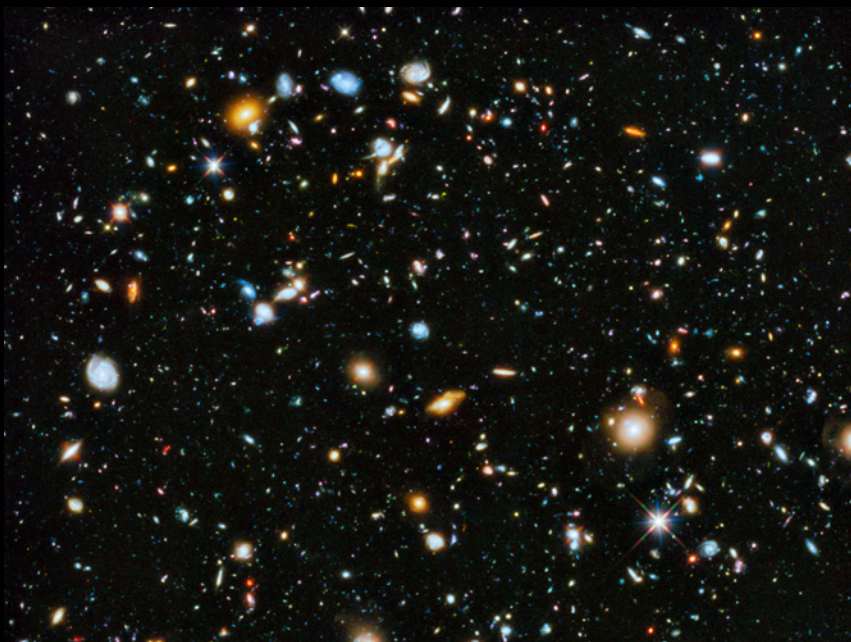
Presented to AIAA Space 2015  
September 1, 2015

Benjamin B. Reed  
Deputy Project Manager  
Satellite Servicing Capabilities Office  
<http://ssco.gsfc.nasa.gov>

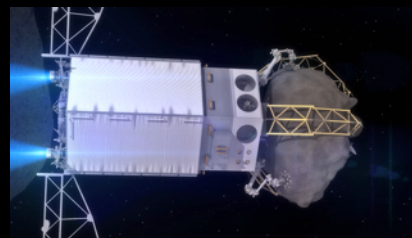
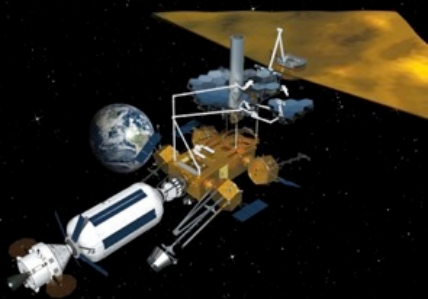
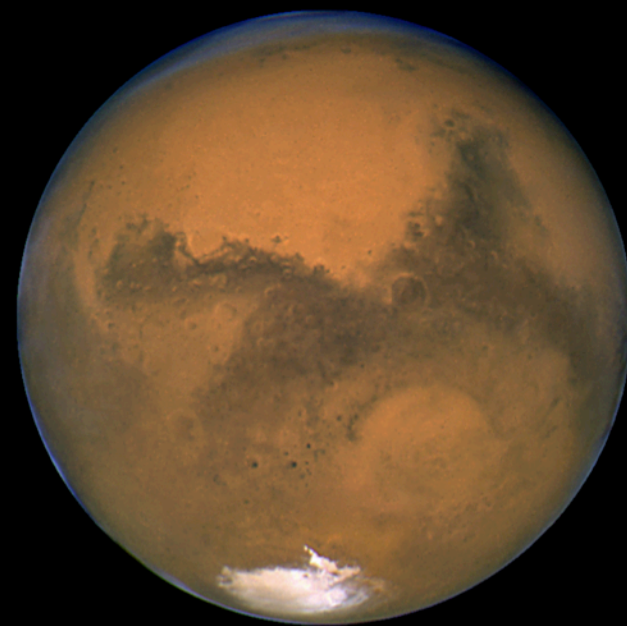
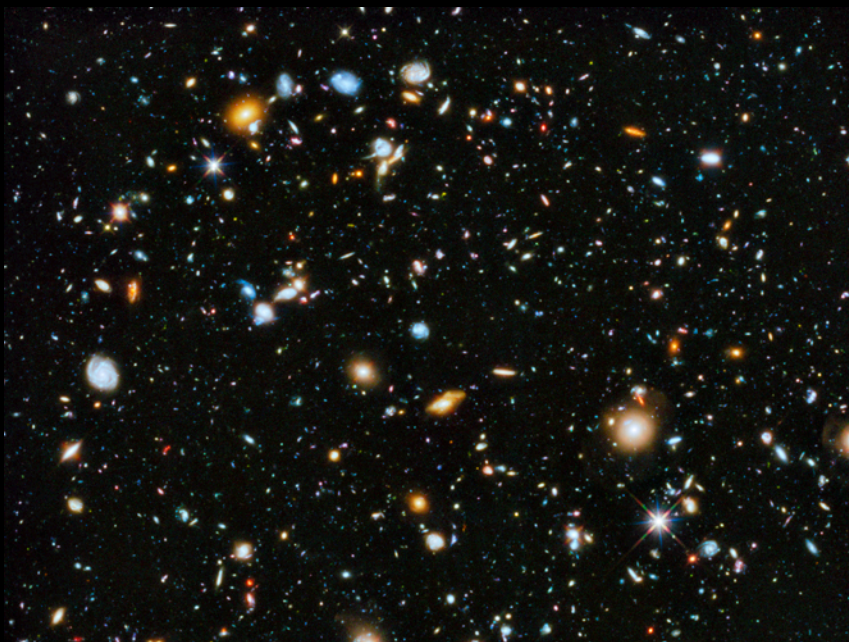
Authors:  
Benjamin Reed, Michael Kienlen, Bo Naasz,  
Brian Roberts and Keith DeWeese  
*NASA/Goddard Space Flight Center*



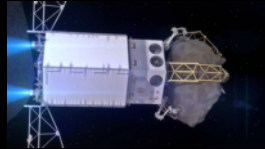
# Are we alone?



# Are we alone?



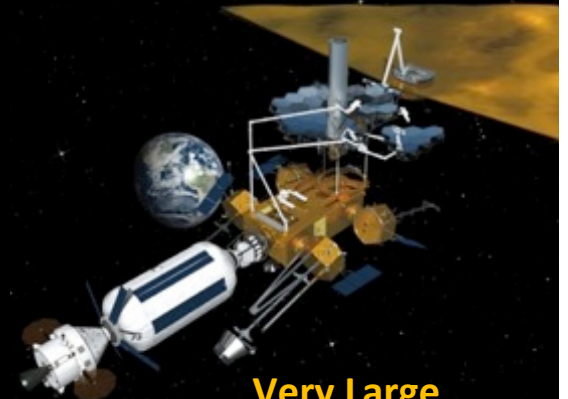
# NASA's Ambitious Objectives



**Asteroid  
Redirection**



**Human  
Exploration**



**Very Large  
Observatories**



**Resilient Fleets**



**Infrastructure Upkeep**



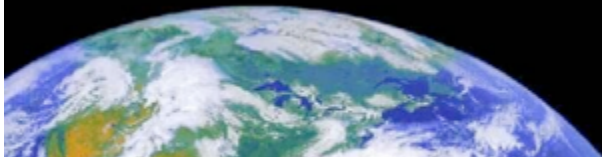
**Observatory  
Servicing**



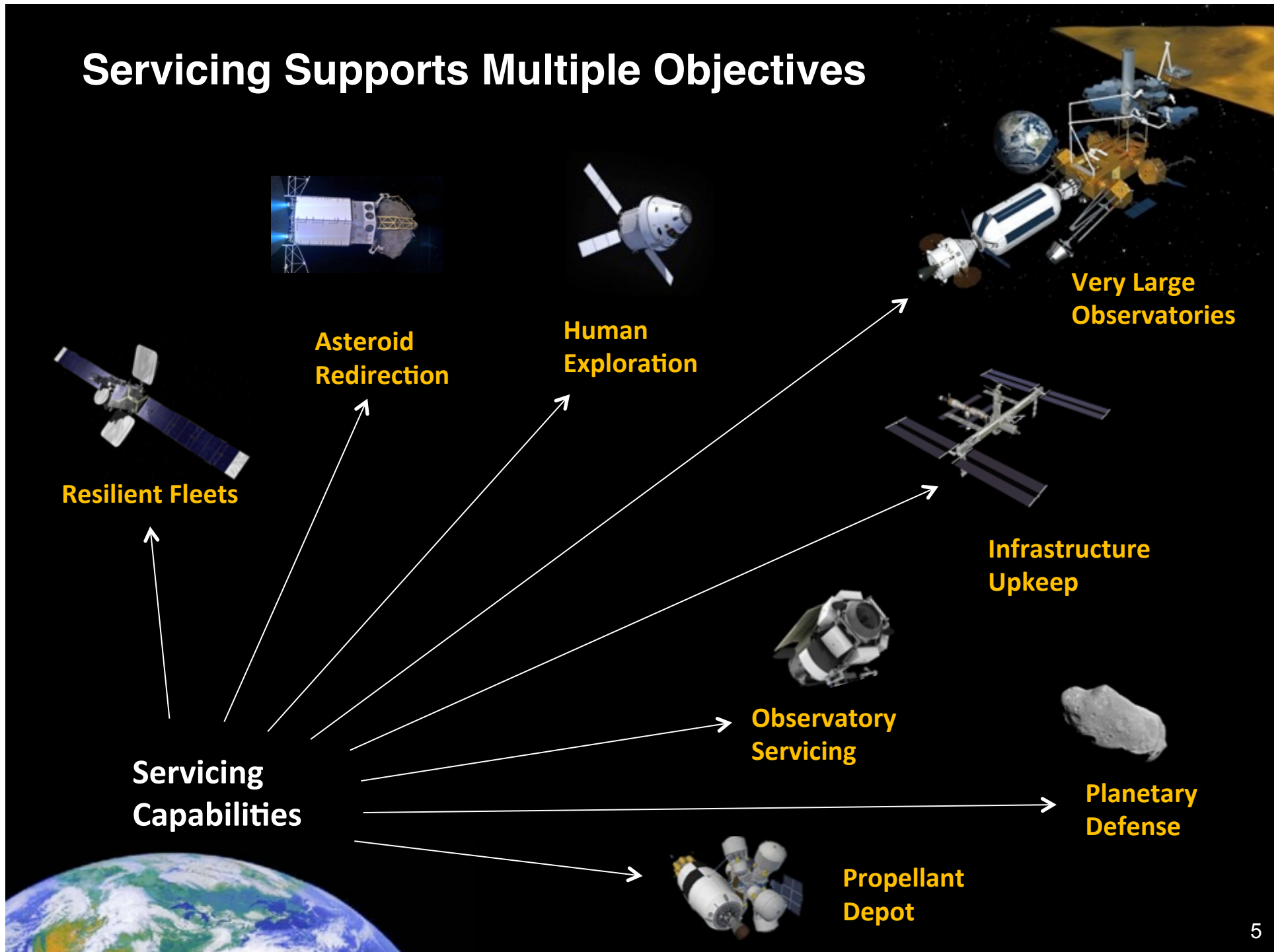
**Planetary  
Defense**



**Propellant  
Depot**



# Servicing Supports Multiple Objectives

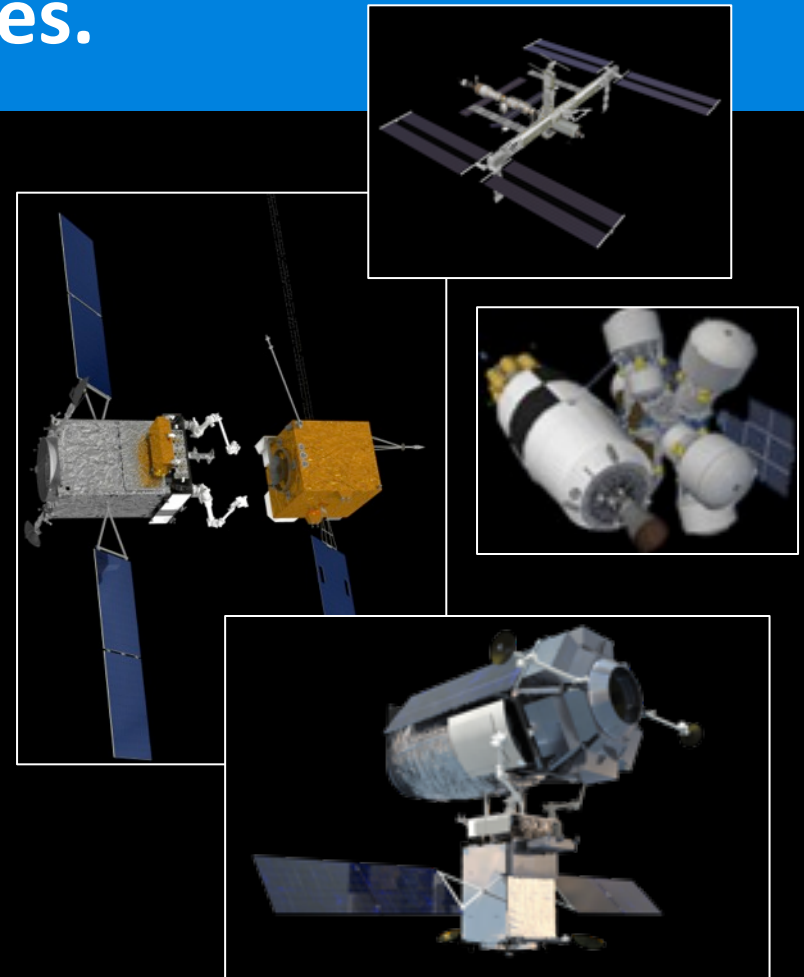


# Satellite Servicing Capabilities



Servicing provides capabilities for **flexible, resilient architectures.**

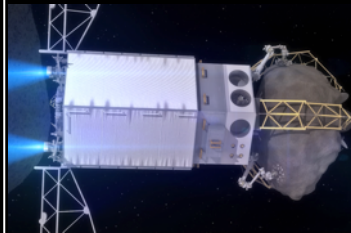
- Anomaly Recovery
- Life Extension
- Component Upgrade
- In-Orbit Assembly
- Consumable Restoration
  - Propellant Refueling
  - Cryogen Replenishment
  - Xenon Recharging



# Servicing Capabilities Help Visions Become Reality



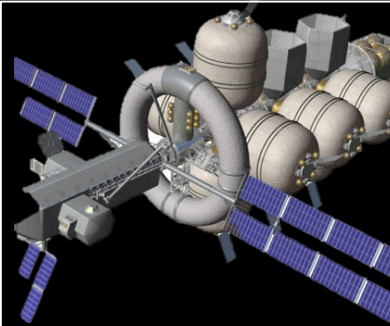
## Human Exploration



**Autonomous  
rendezvous and  
docking**



**Enables modular  
architectures and  
lower-cost launch  
vehicles**



**Construction and  
self-maintenance  
of exploration  
spacecraft**



**Supports long-  
duration stays  
in orbit**



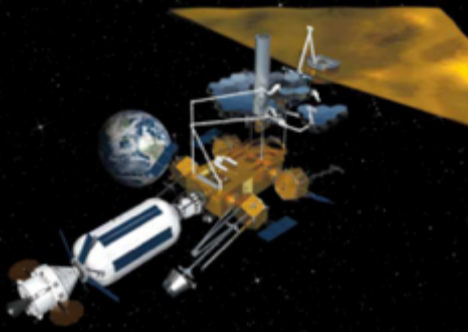
**In-situ  
resource utilization  
machinery**



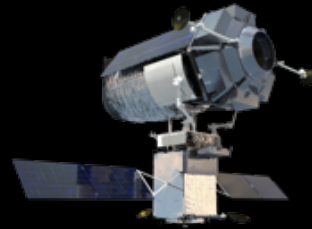
**Helps crew  
produce resources  
to facilitate the  
return voyage**

**Servicing capabilities facilitate robust, resilient, on-orbit human architectures.**

# Servicing Capabilities Help Visions Become Reality



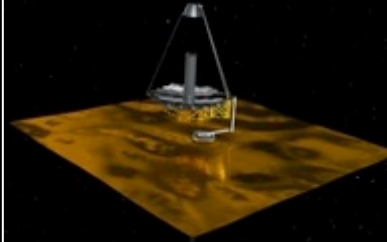
**Very Large  
Observatories**



**Modular,  
upgradable  
spacecraft**



**Flexibility to react  
to new discoveries  
and changes in  
new satellite  
technologies**



**Construction of  
large-aperture  
observatories**



**Discovery and  
characterization of  
exo-Earths**



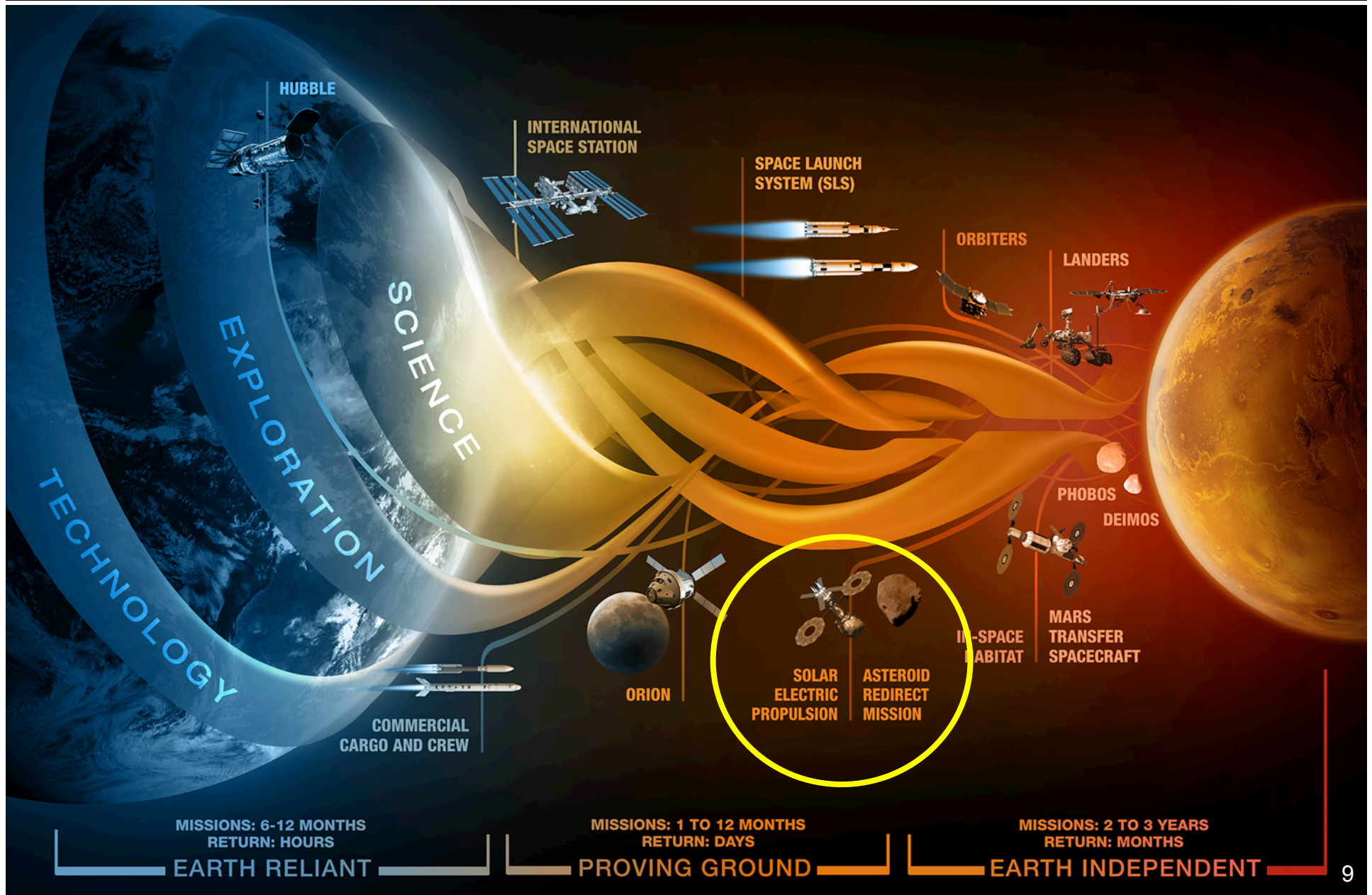
**Construction of  
commercial space-  
based solar power  
satellites**



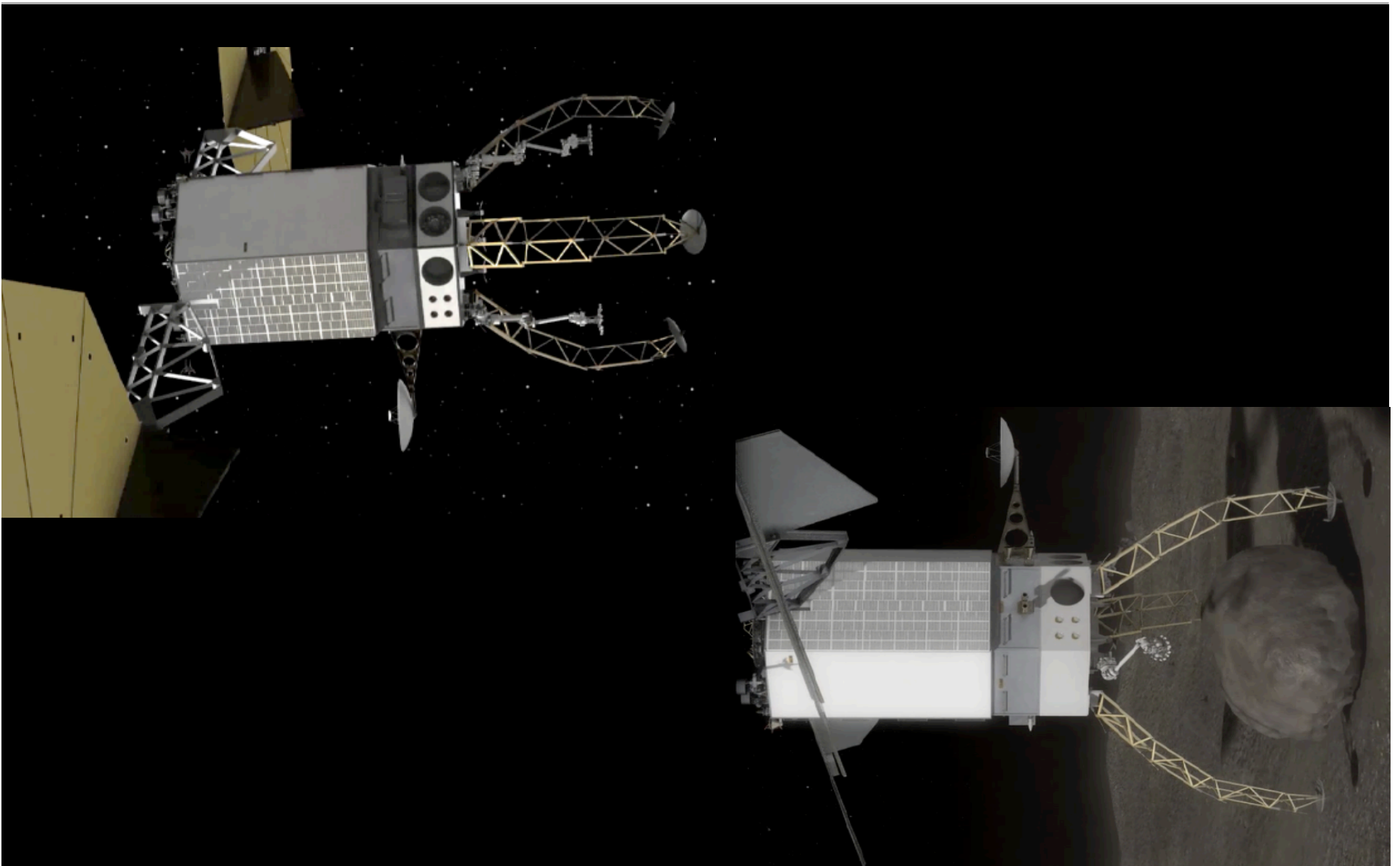
**Transmit vast  
quantities of  
solar energy  
to ground**

**Servicing capabilities facilitate more complex and capable structures to unlock the secrets of the universe.**

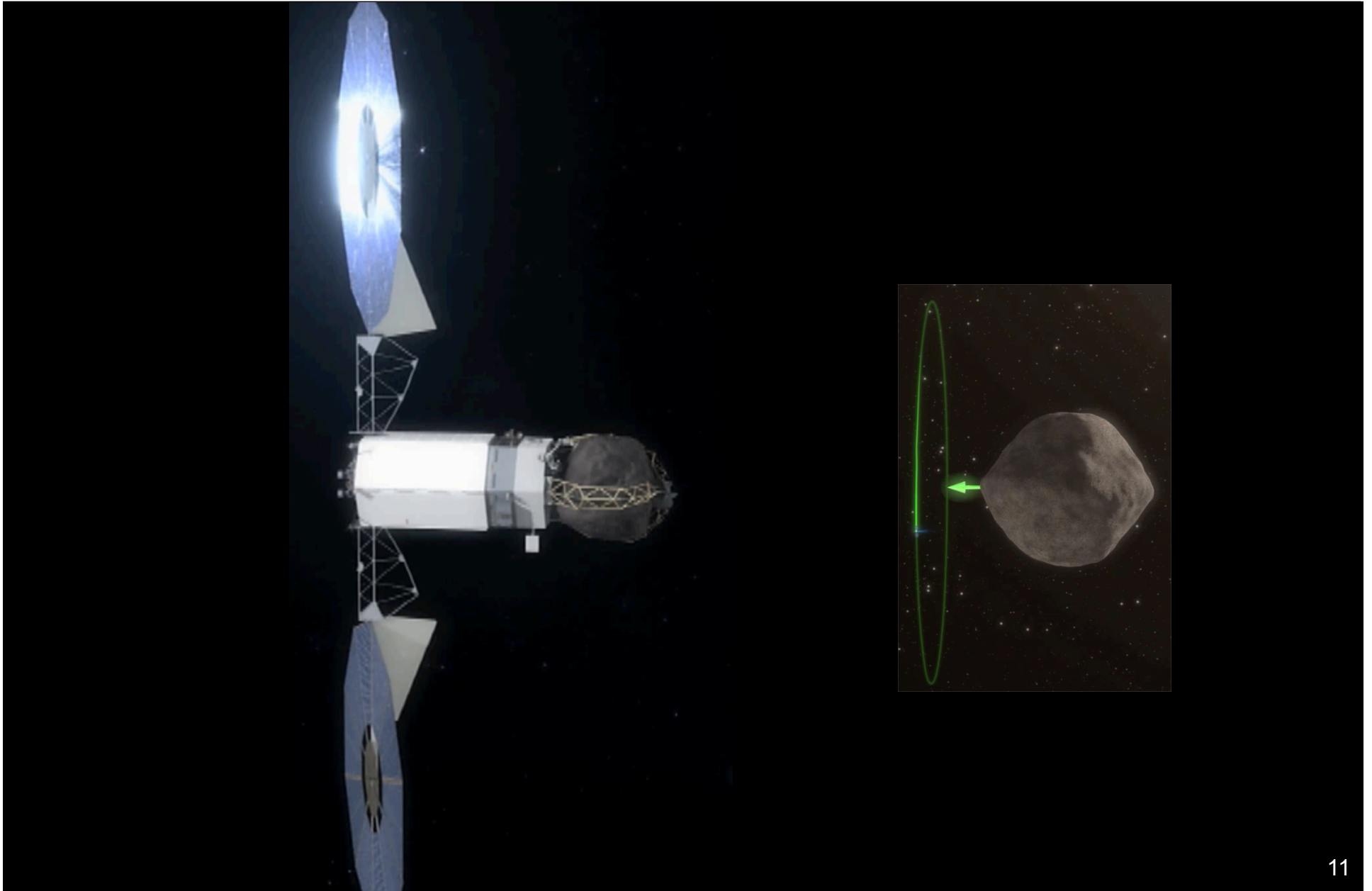
# Servicing Facilitates Exploration



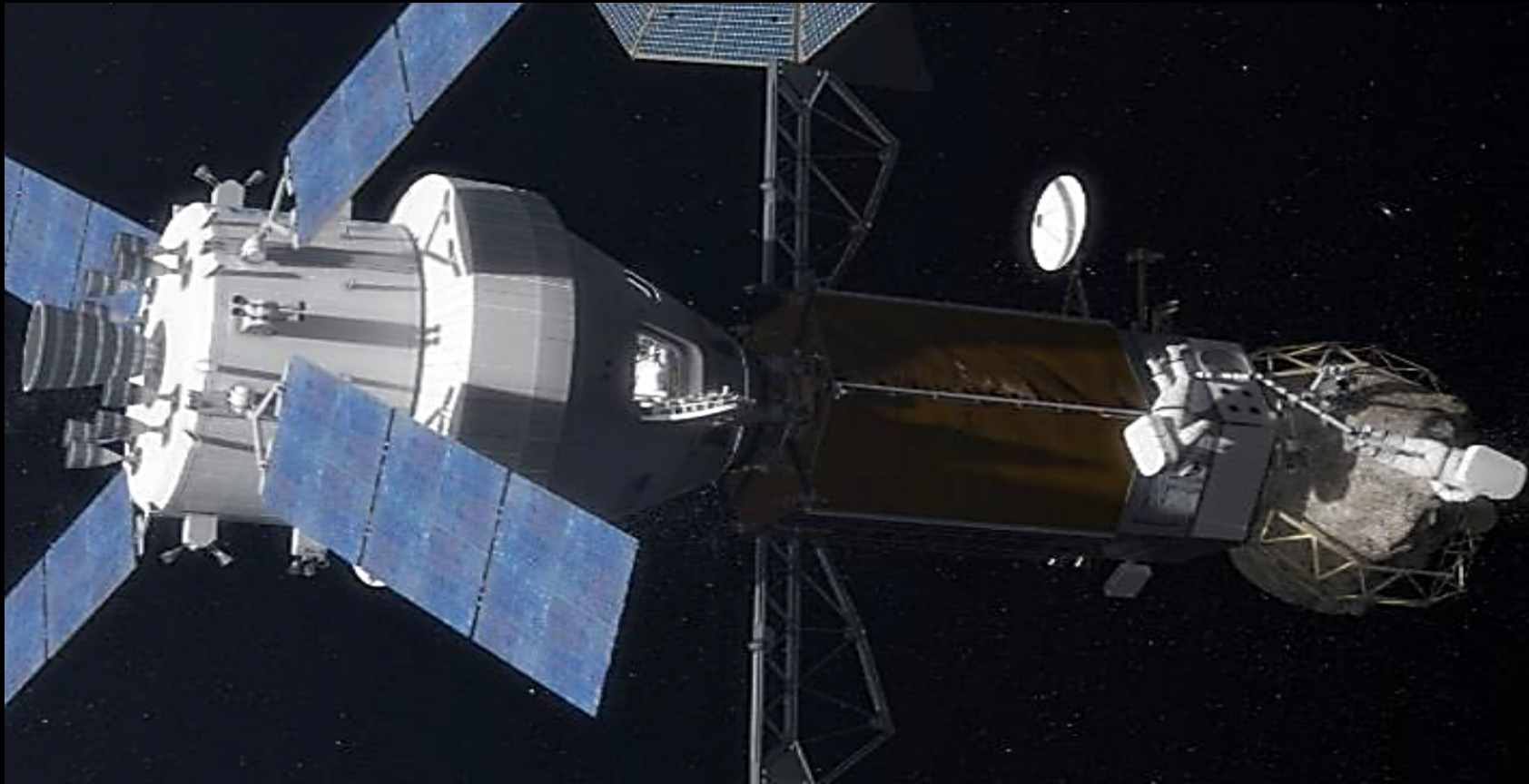
# Asteroid Redirect Mission



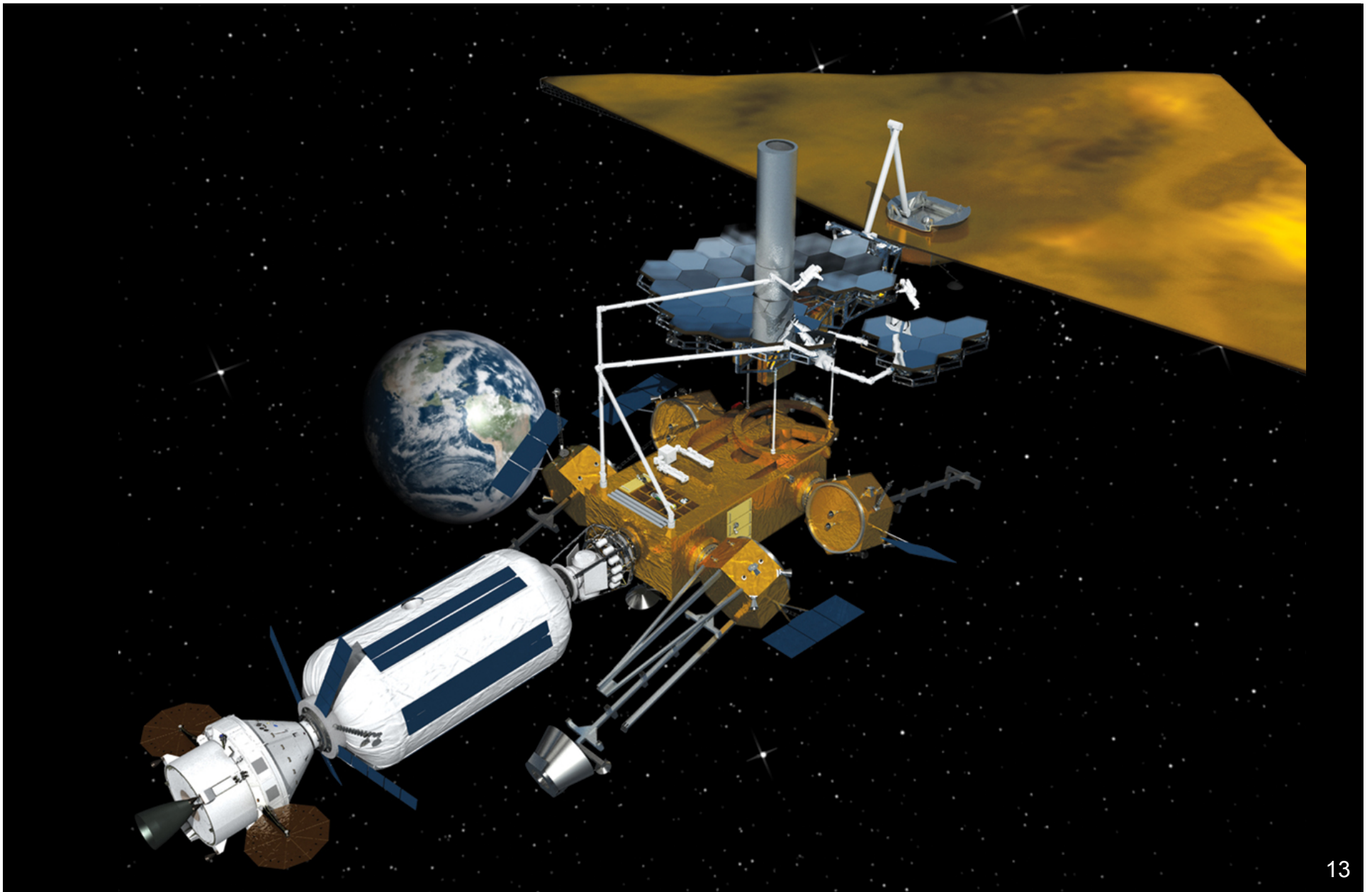
# Asteroid Redirect Mission



# Asteroid Redirect Mission



# Very Large Observatories



# Core Technologies Required for Servicing Capabilities



## Advanced Technologies



## Robust Capabilities

Rendezvous and Proximity Operations

Dexterous Robotics

High-Speed, Fault-Tolerant Computing

Advanced Tools

Fluid Transfer

Anomaly Recovery

Instrument Upgrade

Life Extension

In-Orbit Assembly

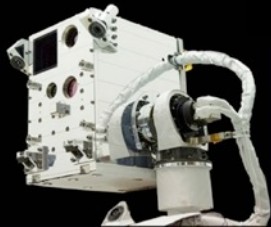
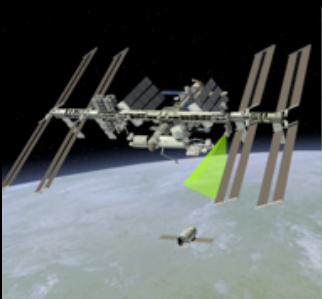
Consumable Restoration

**Technology readiness of core technologies is an important first step on path to capability realization.**

# Servicing Technologies Under Development

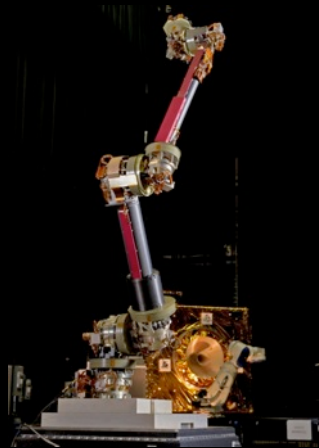


## Rendezvous and Proximity Operations



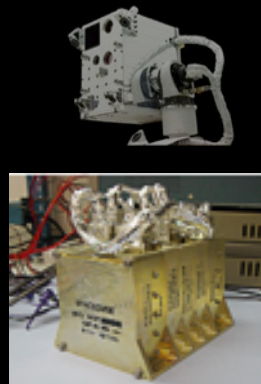
Raven demonstration launches to ISS in 2016

## Dexterous Robotics



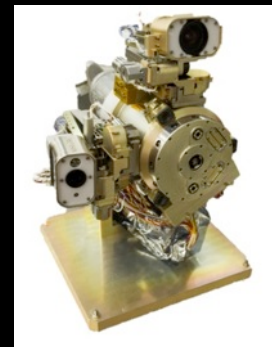
Engineering Design Unit of NASA Servicing Arm undergoing testing and evaluation

## High-Speed, Fault-Tolerant Computing



Next generation of SpaceCube underway

## Advanced Tools



Third generation of advanced robotic tools in manufacturing

## Propellant Transfer



Propellant Transfer System developed & undergoing testing

# Path Forward



## Advanced Technologies



## Robust Capabilities



## Enabled Missions

Rendezvous and  
Proximity Operations

Dexterous Robotics

High-Speed, Fault-  
Tolerant Computing

Advanced Tools

Fluid Transfer

Anomaly Recovery

Instrument Upgrade

Life Extension

In-Orbit Assembly

Consumable Restoration

Very Large  
Observatories

Asteroid Redirection

ISS Maintenance

Human Exploration

Planetary Defense

Propellant Depot

**Significant technology advancement has resulted in servicing capabilities becoming verified. This solid foundation is enabling mission planners to design rich future architectures.**